CALTRANS ENGINEERING SERVICE CENTER

POST EARTHQUAKE INVESTIGATION TEAM REPORT

THE HECTOR MINE EARTHQUAKE

OF OCTOBER 16, 1999

Post Earthquake Investigation Team Report

<u>Performance of Bridges during the Hector Mine Earthquake of October 16, 1999</u>

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I. INTRODUCTION

Although the Hector Mine Earthquake caused little bridge damage, it still has lessons to teach bridge and earthquake engineers. For instance, it is unclear why a very large (M > 7) earthquake should have little effect on bridges less than 10 miles from the fault rupture (Figure 1). It would be simplistic to say that the lack of damage was due to Caltrans efforts to retrofit and design safer bridges. Caltrans designs bridges not to collapse for a magnitude 7 earthquake, but there were few signs that the columns even had large displacements during this event. The idea that the scarcity of bridges in the desert may be responsible for the lack of damage seems unlikely since we have seen powerful earthquakes knock down bridges over 100 km away. Perhaps the surface faulting may have absorbed some of the energy that would otherwise have created larger accelerations. Obviously, more research into why very large earthquakes often cause little bridge damage is needed.

The peak ground motion (PGA) recorded during the earthquake was extremely low (0.19 g). However, this seems more indicative of the lack of instruments in the area then of the actual size of the ground motion. The maximum acceleration was recorded over 50 km away from the epicenter.

Caltrans has many instrumented bridges in Southern California, but none in the immediate vicinity of the fault rupture. Table 1 provides the PGA and other data recorded at Caltrans bridge sites. Because this part of the Mojave is so seismically active, it would be prudent to instrument at least one bridge in the area.

Table 1. Peak Acceleration Data on Caltrans Bridges from the Hector Mine Earthquake.

Sta. #	**Station Name**	**Lat.**	**Long.**	**Dist.** km	**PGA**	**Struc.**
12666	N. Palm Springs - I10/62 Interchange Br	33.915	116.608	82.1	0.134g	0.330g
23631	San Bernardino - I10/215 Interchange Br	34.064	117.296	111.6	0.110g	
13705	Corona - I15/Hwy91 Interchange Bridge	33.882	117.548	142.1	0.035g	0.092g
24706	Palmdale - Hwy 14/Barrel Springs Br	34.546	118.129	170.7	0.033g	0.081g
13795	Capistrano Beach - I5/Via Calif. Bridge	33.466	117.666	180.1	0.009g	0.024g
24689	Pasadena - I210/Hwy134 Interchange Br	34.150	118.154	180.3	0.047g	
34715	Mojave - Hwy 14/Railroad Bridge	35.038	118.169	180.4	0.107g	0.194g
33742	Ridgecrest - Hwy 395/Brown Road Br	35.670	117.818	184.4	0.025g	0.078g
24704	Los Angeles - I10/La Cienega Bridge	34.037	118.376	203.6	0.026g	0.100g
03679	San Diego - Coronado Bridge	32.688	117.154	227.4	0.016g	
25758	Cuyama - Hwy 166/Cuyama River Br	34.930	119.600	307.0	0.012g	0.044g

Updated: 10/20/99 5:00 p.m.

Because of the large magnitude of this earthquake, several groups from Caltrans went to investigate. The Southern Area Bridge Maintenance Engineer (ABME) headed by Ben Vorobieff was on the site within a few hours of the earthquake. Caltrans' Post-Earthquake Investigation Team (PEQIT) made up of Jaroslav Simek and Ganapathy Murugesh followed soon after. Caltrans' Seismologist, Laliana Mualchin made a visit a few days later, as did Charles Sikorsky, a Caltrans bridge engineer in Caltrans' Office of Earthquake Engineering. Sikorsky had recently performed an ambient vibration test on Lavic Road OC due to a problem with active silica reactivity (ASR) and was anxious to see if he could identify further damage on the structure through subsequent vibration testing. The findings of all of these groups are in this report.

Figure 1. Area Map

The early morning earthquake struck in a remote region of the state of California and was felt in San Diego, Los Angeles, Phoenix and Las Vegas.

II. SEISMOLOGIST'S REPORT

Impact on the Caltrans California Seismic Hazard Map

The Hector Mine Earthquake is associated with the Pisgah-Bullion fault, depicted in the Caltrans' California Seismic Hazard map. Figure 2 shows the area affected by the Hector Mine earthquake. The southern portion of the fault rupture is the Bullion Fault and the northern portion is the Lavic Lake Fault. It is only 2 to 4 miles east of the Pisgah-Bullion fault. The fault causing the Hector Mine earthquake connected these two faults in the same way that the 1992 Landers earthquake connected several adjacent faults, namely Camp Rock, Emerson-Copper Mountain, Homestead Valley, and Johnson Valley faults. The MCE for the Pisgah-Bullion fault is moment magnitude 7 that is comparable to the Hector Mine earthquake. However, the fault zone should be re-examined for a conservative estimate of its MCE moment magnitude.

The associated strong ground motions for the Hector Mine earthquake were already included in the Caltrans Seismic Hazard map. However, since a portion of the fault is 2 to 4 miles east of the Pisgah-Bullion fault, the PGA's will be larger on the eastern side of the fault. It is the intent to incorporate this in Caltrans Seismic Hazard Map.

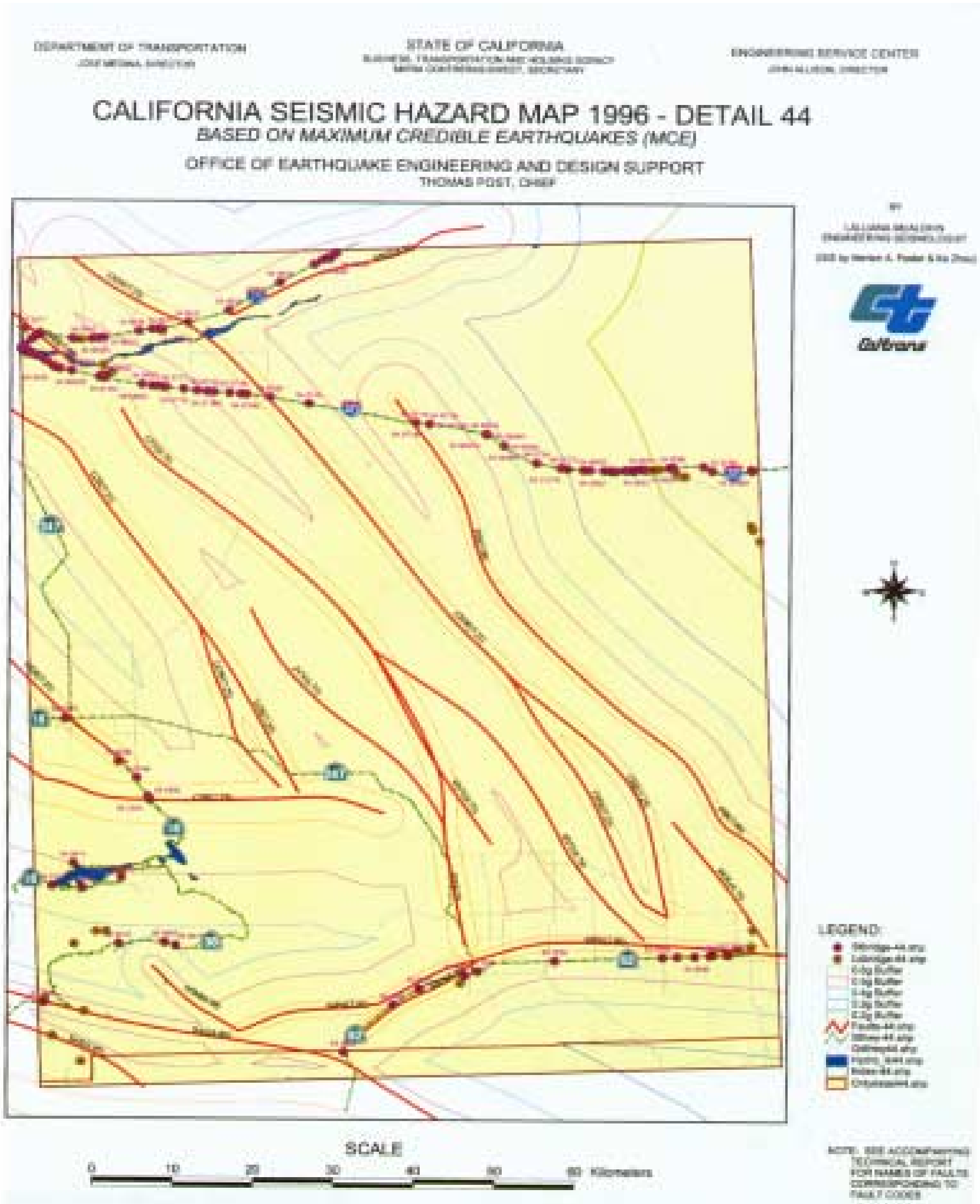

Figure 2. Caltrans' Seismic Hazard Map of the Hector Mine Earthquake Region.

Implications for the Caltrans California Seismic Hazard Map

There are two principal approaches addressing seismic hazard. More theoretical "Probabilistic", and practical "Deterministic" approach. The "Deterministic" approach employed by Caltrans effectively considers faults such as the source of the Hector Mine earthquake. Similarly deterministic approach considered faults causing the 1992 Landers and 1994 Northridge earthquakes. Since the Hector Mine earthquake is centered on a fault that is not as active as the faults located on the coast, probabilistic maps did not adequately address its occurrence.

As a consequence of the Hector Mine earthquake and recent developments in the understanding of faults in the region, faults that were not considered in current Caltrans Seismic Hazard map will be investigated for possible inclusion. An inspection of seismic records, and trenching near the faults may indicate recent tectonic activity. For example, if the Ludlow fault, which was included in the previous Caltrans map, is found to be seismically active, it will be re-considered in the seismic hazard map.

Recent trenching of faults in the Mojave desert by geologists, found that tectonic activity occurred in clusters during three time periods: in the past 2,000 years before present, between 4,500 and 6,500 years ago, and between 8,000 and 10,000 years ago. Such knowledge may be applied in the future for selecting faults for inclusion in seismic hazard maps.

Summary and Recommendations

1. The approach used by Caltrans in the 'Deterministic Seismic Hazard Estimate' adequately considers faults such as the Hector Mine earthquake source. As the fault had relatively low activity, a probabilistic method might miss such potential seismic hazards. Deterministic approach has been successfully used for the case of the Landers and Northridge earthquakes.
2. The Hector Mine earthquake is centered on the Pisgah-Bullion fault system. The northern section of the fault was not well documented. Now it should be considered in the "California Seismic Hazard Map". The fault zone of the Pisgah-Bullion system should be reevaluated by incorporating this earthquake and revising its MCE moment magnitude.
3. No significant change in PGA values is anticipated. The minor change is likely in the near-field region to reflect revised MCE.
4. The distribution of surface displacements is a complex phenomenon. The understanding of this distribution is essential for Caltrans in designing and evaluating bridges that cross faults.
5. Fault zone mapping with trapped-waves should be considered in Caltrans projects. The method has been successfully demonstrated in a number of cases and can be done economically and quickly. Where trenching may not show fault locations, trapped-waves method may be able to do so.
6. The other faults in the Mojave desert region that are not included in the current "Caltrans Seismic Hazard Map" should be re-examined for possible inclusion.
7. Bridges in the strong ground-shaking region did not suffer significant damage. It is important to study the reasons (seismic waves, site conditions, and engineering) why bridges performed well during the Hector Mine earthquake.
8. Strong motion records at bridge sites should be catalogued systematically and used actively for bridge engineering. It is important that cataloging be done before unmanageable data is being accumulated.
9. Various agencies (USGS, SCEC, CDMG, and others) provide valuable information such as maps, imageries, etc., on earthquakes speedily. Caltrans should be able to receive and use this information by employing new technology. New information systems should be provided to responsible groups and individuals. Obtaining information quickly will be critical to our effective response during future damaging earthquakes.

III. AREA BRIDGE MAINTENANCE ENGINEER REPORT

Caltrans divides the state into a Northern and Southern region for bridge maintenance, with the Southern Area Bridge Maintenance Engineers (ABME) located in Los Angeles. Within hours after the earthquake, the Southern ABME was mobilized and on their way to the site, about 150 miles away. Within the next two days the highways indicated in Figure 3 were inspected.

Caltrans uses Post Miles (P.M.) on the highway to locate bridges. The ABME inspected Route 15 from P.M. 55.69 to P.M. 147.65 and Route 40 from P.M. 00.00 to P.M. 85.21 (Figure 10). A complete list of all inspected bridges is provided in Tables 2 and 3. However, the only bridges found to have any damage were Lavic Road Overcrossing (Bridge No. 54-0734) and the two parallel Pisgah Overhead bridges (Bridge No. 54-0689L/R).

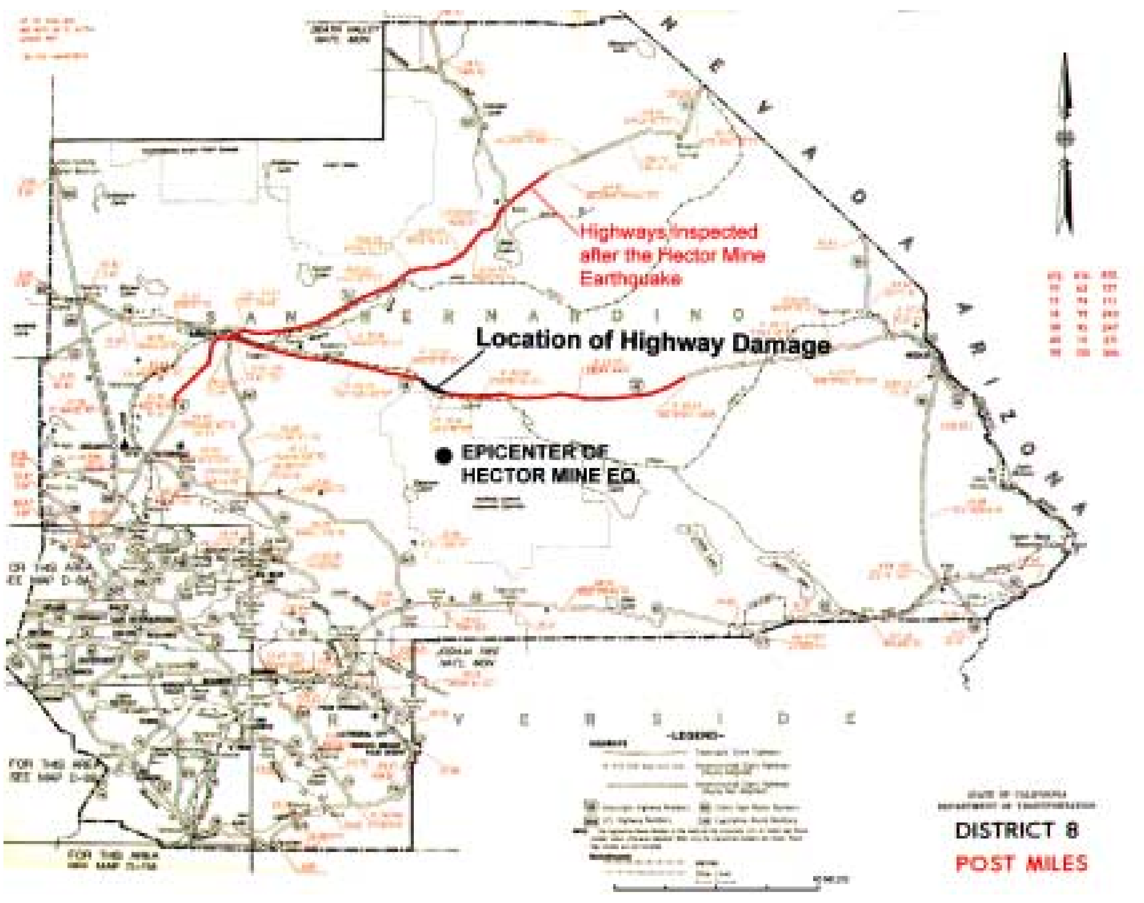

Figure 3. Map Showing Highways Inspected by Bridge Maintenance Engineers (ABME).

TABLE 2. Bridges Inspected on Route 15.

Postmile, O/U, Bridge #, Structure Name	Postmile, O/U, Bridge #, Structure Name	Postmile, O/U, Bridge #, Structure Name
_055.690 O 54 0500L WILD WASH	R081.830 O 54 0627R GHOST TOWN ROAD UC	R120.050 O 54 0642R MOJAVE RIVER OVERFLOW
_055.690 O 54 0500R WILD WASH	R084.640 U 54 0628 CALICO ROAD OC	R120.430 U 54 0383 BASIN ROAD OC
_055.960 U 54 0565 WILD WASH ROAD	R085.650 U 54 0629 FIRST STREET OC	R121.430 O 54 0246L DOCK DITCH
_060.160 U 54 0566 HODGE ROAD OC	R086.050 O 54 0667L YERMO DITCH	R121.430 O 54 0246R DOCK DITCH
_065.840 U 54 0567 OUTLET CENTER DRIVE OC	R086.050 O 54 0667R YERMO DITCH	R123.090 O 54 0247L TONO DITCH
_068.190 O 54 0573 DRIFT WASH	R086.380 U 54 0631 EAST YERMO OC	R123.110 O 54 0247R TONO DITCH
_068.480 O 54 0511L LENWOOD WASH	R088.490 U 54 0632 MINNEOLA ROAD OC	R124.240 U 54 0391 RASOR ROAD OC
_068.480 O 54 0511R LENWOOD WASH	R091.810 U 54 0633 COYOTE LAKE ROAD OC	R126.860 O 54 0251L OPAH DITCH
_068.770 U 54 0568 LENWOOD ROAD OC	R096.410 U 54 0634 HARVARD ROAD OC	R126.860 O 54 0251R OPAH DITCH
_070.100 O 54 1114L ROUTE 15/58 SEPARATION	R099.490 U 54 0635 ALVORD MTN ROAD OC	R130.180 U 54 0398 ZZYZX ROAD OC
_070.100 O 54 1114R ROUTE 15/58 SEPARATION	R100.230 O 54 0636L WEST MANIX WASH	R130.580 O 54 0270L OAT DITCH
_071.600 O 54 1115L "L" STREET UNDERCROSSING	R100.230 O 54 0636R WEST MANIX WASH	R130.590 O 54 0270R OAT DITCH
_071.600 O 54 1115R "L" STREET UNDERCROSSING	R100.670 O 54 0637L EAST MANIX WASH	R135.050 O 54 0277L MOBI DITCH
_071.650 U 54 0556S WEST MAIN ST OFF-RAMP OC	R100.670 O 54 0637R EAST MANIX WASH	R135.050 O 54 0277R MOBI DITCH
_071.720 U 54 0557S WEST MAIN ST OFF-RAMP OC	R101.270 O 54 0638L MOUND WASH	R135.810 U 54 0609S WEST BAKER OFF-RAMP OC
_071.920 U 54 0555C WEST MAIN ST ON-RAMP OC	R101.270 O 54 0638R MOUND WASH	R136.130 O 54 0278R MOJAVE RIVER
_072.130 O 54 0551L AVENUE H UC	R101.480 O 54 0639L FLAT DITCH	R136.150 O 54 0278L MOJAVE RIVER
_072.130 O 54 0551R AVENUE H UC	R101.480 O 54 0639R FLAT DITCH	R136.570 U 54 0610 ROUTE 127/15 SEPARATION
_073.540 U 54 0552 BARSTOW ROAD SEPARATION	R103.630 U 54 0640 FIELD ROAD OC	R136.950 O 54 0279L BAKER INN DITCH
_074.150 U 54 1174 MURIEL DRIVE OC	R104.770 O 54 0223L FIELD WASH	R136.950 O 54 0279R BAKER INN DITCH
_074.420 U 54 0554F W40-S15 CONNECTOR OC	R104.770 O 54 0223R FIELD WASH	R138.460 U 54 0611S EAST BAKER OC
_074.950 U 54 0545 EAST MAIN STREET OC	R105.970 O 54 0225L CADY WASH	R138.700 O 54 0281L PANO DITCH
_075.040 U 54 0546 EAST BARSTOW UP	R105.970 O 54 0225R CADY WASH	R138.720 O 54 0281S PANO DITCH
_075.090 U 54 0547 RIVERSIDE DRIVE OC	R107.120 O 54 0227L MIDWAY DITCH	R138.730 O 54 0281R PANO DITCH
_075.310 O 54 0548L MOJAVE RIVER	R107.120 O 54 0227R MIDWAY DITCH	_139.200 O 54 0282L BERRY DITCH
_075.310 O 54 0548R MOJAVE RIVER	R110.360 O 54 0233L TELEPHONE WASH	_139.220 O 54 0282R BERRY DITCH
_076.020 O 54 0549L SOAP MINE ROAD UC	R110.360 O 54 0233R TELEPHONE WASH	_142.260 O 54 0283L HACK WASH
_076.020 O 54 0549R SOAP MINE ROAD UC	R111.590 U 54 0364 AFTON ROAD OC	_142.260 O 54 0283R HACK WASH
_076.880 U 54 0550E ROUTE 58/15 SEPARATION	R115.360 O 54 0238L BIRD DITCH	_147.640 O 54 0287R HALLORAN WASH
_076.900 O 54 0212F HIKER DITCH	R115.360 O 54 0238R BIRD DITCH	_147.650 O 54 0287L HALLORAN WASH
_079.590 U 54 0559 FORT IRWIN ROAD OC	R116.820 O 54 0239 ROCKY WASH	
R081.830 O 54 0627L GHOST TOWN ROAD UC	R120.050 O 54 0642L MOJAVE RIVER OVERFLOW	

TABLE 3. Bridges Inspected on Route 40.

Postmile O/U Bridge Structure Name	Postmile O/U Bridge Structure Name	Postmile O/U Bridge Structure Name
000.010 O 54 0554F W40-S15 CONNECTOR OC	R012.190 O 54 0732L AIRPORT ROAD UC	R049.980 O 54 0735L CRUCERO ROAD UC
_000.460 O 54 0784 BLAIR DITCH	R012.190 O 54 0732R AIRPORT ROAD UC	R049.980 O 54 0735R CRUCERO ROAD UC
_000.720 U 54 0558L MONTARA ROAD UC	R013.550 O 54 0713L AIRPORT WASH	R051.870 O 54 0085L TRANS DITCH
_000.720 U 54 0558R MONTARA ROAD UC	R013.550 O 54 0713R AIRPORT WASH	R051.870 O 54 0085R TRANS DITCH
_000.790 O 54 0558L MONTARA ROAD UC	R014.610 O 54 0714L LAVA WASH	R052.120 O 54 0086 CIRCLE DITCH
_000.790 O 54 0558R MONTARA ROAD UC	R014.610 O 54 0714R LAVA WASH	R054.090 O 54 0757L BROADWELL WASH
R001.250 O 54 0692 VICTOR DITCH	R015.410 O 54 0715L GAS LINE WASH	R054.090 O 54 0757R BROADWELL WASH
R001.600 O 54 0654L DEAN WASH	R015.410 O 54 0715R GAS LINE WASH	R054.750 O 54 0758L ASH HILL WASH
R001.600 O 54 0654R DEAN WASH	R015.920 O 54 0716L TWIN HILLS WASH	R054.770 O 54 0758R ASH HILL WASH
R002.080 O 54 0655 HOLIDAY WASH	R015.920 O 54 0716R TWIN HILLS WASH	R057.610 O 54 0759L BISMARCK WASH
R002.320 O 54 0693 STAPP DITCH	R017.100 O 54 0884L STRIPE MOUNTAIN DITCH	R057.630 O 54 0759R BISMARCK WASH
R002.350 O 54 0656L EAST MAIN STREET UC	R017.100 O 54 0884R STRIPE MOUNTAIN DITCH	R058.970 O 54 0760L BRISTOL MOUNTAIN WASH
R002.350 O 54 0656R EAST MAIN STREET UC	R018.030 O 54 0717L CREST WASH	R058.980 O 54 0760R BRISTOL MOUNTAIN WASH
R002.670 U 54 0657 CAPE GLOUCESTER OC	R018.030 O 54 0717R CREST WASH	R060.800 O 54 1006L EDELWEISS DITCH
R003.250 O 54 0658 PELELIU DITCH	R018.430 O 54 0708L NATIONAL TRAILS HWY UC	R060.800 O 54 1006R EDELWEISS DITCH
R003.430 O 54 0659L IWO JIMA STREET UC	R018.430 O 54 0708R NATIONAL TRAILS HWY UC	R065.590 O 54 0848R SIBERIA WASH
R003.430 O 54 0659R IWO JIMA STREET UC	R020.270 U 54 0709 NEWBERRY ROAD OC	R065.800 O 54 1013L LEEK DITCH
R003.810 O 54 0660L WONSAN DITCH	R023.330 U 54 0710 FORT CADY ROAD OC	R071.100 O 54 1017L PARSLEY DITCH
R003.810 O 54 0660R WONSAN DITCH	R031.420 O 54 0718L LAVA DITCH	R071.750 O 54 0849L ORANGE BLOSSOM WASH
R004.710 O 54 0662L NEBO STREET UC	R031.420 O 54 0718R LAVA DITCH	R071.750 O 54 0849R ORANGE BLOSSOM WASH
R004.710 O 54 0662R NEBO STREET UC	R032.500 O 54 0719L HECTOR ROAD UC	R073.100 O 54 1020 SAGE DITCH
R006.940 O 54 0699L ORD DITCH	R032.500 O 54 0719R HECTOR ROAD UC	R074.510 O 54 0850L OLD DAD WASH
R006.940 O 54 0699R ORD DITCH	R037.270 O 54 0691L PISGAH CRATER ROAD UC	R074.510 O 54 0850R OLD DAD WASH
R007.180 U 54 0663 "A" STREET OC	R037.270 O 54 0691R PISGAH CRATER ROAD UC	R075.500 O 54 0851L BADGER WASH
R007.400 O 54 0785L ROCK DITCH	R037.410 O 54 0689L PISGAH OVERHEAD	R075.500 O 54 0851R BADGER WASH
R007.400 O 54 0785R ROCK DITCH	R037.440 O 54 0689R PISGAH OVERHEAD	R076.500 O 54 0852L GRANITE MOUNTAIN WASH
R010.300 O 54 0881L WYE DITCH	R039.000 O 54 0690L RED WASH	R076.500 O 54 0852R GRANITE MOUNTAIN WASH
R010.300 O 54 0881R WYE DITCH	R039.000 O 54 0690R RED WASH	R077.370 O 54 0853R WILLOW SPRINGS WASH
R011.100 O 54 0882L FORK DITCH	R041.910 U 54 0734 LAVIC RD OC	R077.390 O 54 0853L WILLOW SPRINGS WASH
R011.100 O 54 0882R FORK DITCH	R043.840 O 54 0737L ARGOS WASH	R078.170 O 54 0885L KELBAKER RD UC
R011.450 O 54 0711L BLOOM WASH	R043.840 O 54 0737R ARGOS WASH	R078.170 O 54 0885R KELBAKER RD UC
R011.450 O 54 0711R BLOOM WASH	R049.040 O 54 0736L SAND HILL WASH	R080.420 O 54 0886L MARBLE WASH
R012.000 O 54 0712L BLOSSOM WASH	R049.040 O 54 0736R SAND HILL WASH	R080.440 O 54 0886R MARBLE WASH
R012.000 O 54 0712R BLOSSOM WASH	R049.710 O 54 0079L W LUDLOW WASH	R085.190 O 54 0903L VAN WINKLE WASH
R012.000 O 54 0712S BLOSSOM WASH	R049.710 O 54 0079R W LUDLOW WASH	R085.210 O 54 0903R VAN WINKLE WASH

POST-EARTHQUAKE INSPECTION TEAM REPORT

Lavic Road Overcrossing (Br. # 54-0734)

Lavic Road OC sustained moderate damage during the Hector Mine earthquake. The bridge is a two span reinforced concrete box girder with a single column bent (See General Plan, Figure 5). The damage was limited to the abutments. An inspection of visible sections of the column indicated no signs of cracking and/or distress. The bottom of the column was not inspected, as it is about seven to eight feet below the ground level. The structure experienced movements that resulted in the final displacements of 3" longitudinally, and about 2.5" to 3" in the transverse direction (Refer to Figure 7 and 8). The approach embankments settled approximately ½" to 2".

The integral diaphragm abutment details are inconsistent with current design practice. There are two pin connections, one at the superstructure - abutment wall transition, and the other at the abutment wall - footing connection. The wingwalls are independent and do not tie into the abutment walls. The transverse shear capacity of the abutments was limited to the strength of the dowels at the pin connections. As the abutments moved in the transverse direction, the shear resistance offered by the dowels was exceeded. This resulted in pullout of shear dowels at the edges of the end diaphragm walls (Figures 9 and 10), presumably shearing off the internal dowels. Shear cracks developed at the abutment walls (Figures 4, 9, and 12). The wingwalls rotated about their bases, resulting in a net shift up to 7" at the top of the wingwalls. This maximum displacement occurred in northwest corner of the bridge as is documented by barrier - rail misalignment (Figures 13 and 14). The bridge has concrete slope protection that slightly bulged at both abutments.

It should be noted that this structure was most likely constructed with reactive aggregate. It is our opinion that most of the cracks at the time of earthquake had already developed due to ASR reactivity. The Hector Mine earthquake merely increased the crack width (See Figure 4, 9, and 12).

Figure 4. **54-0734** **Lavic Road OC**

Spalling and damage at North abutment due to transverse movement.

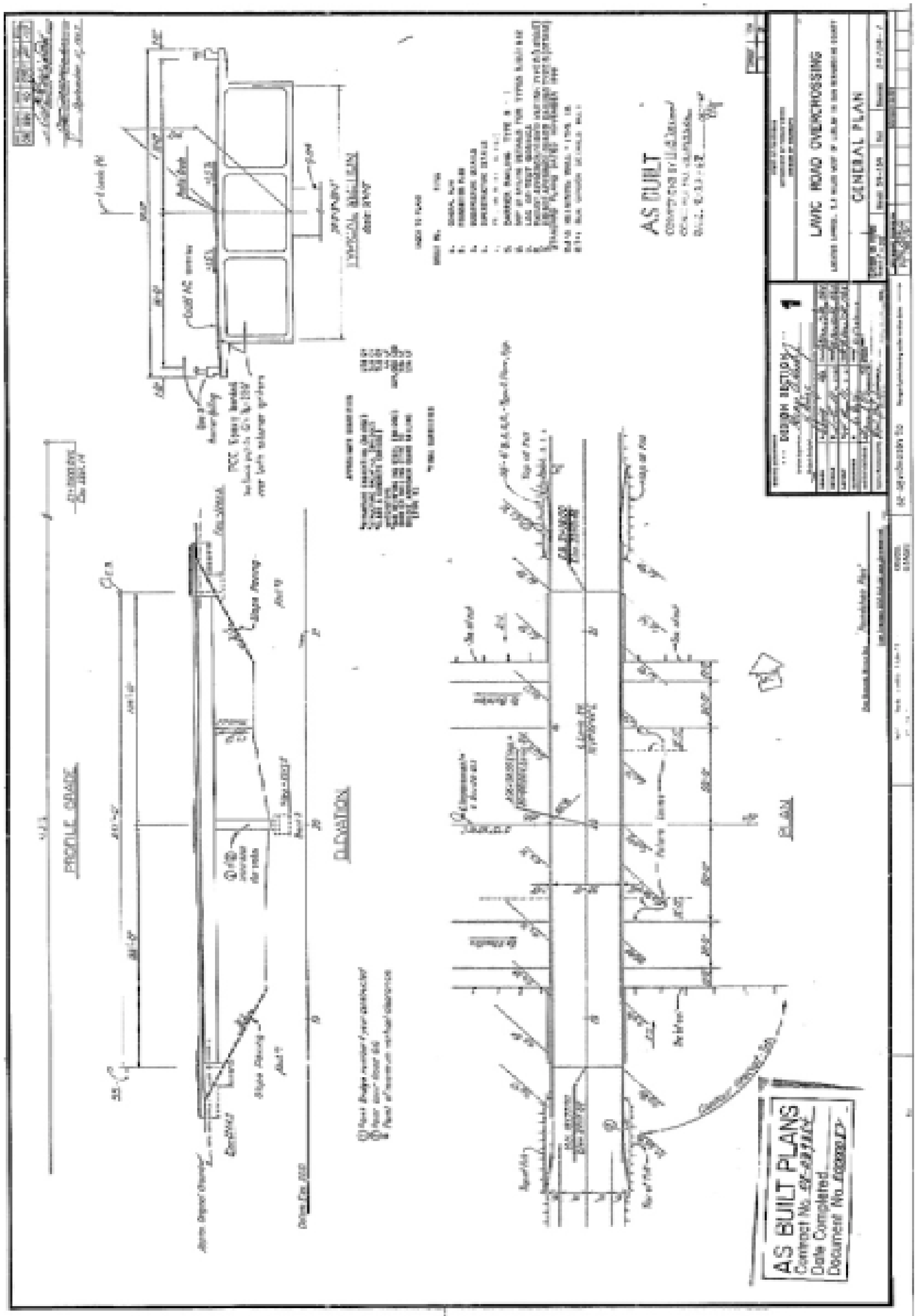

Figure 5. Lavic Road Overcrossing General Plan.

Figure 6. **54-0734** **Lavic Road OC**

Damage at south abutment expansion joint due to longitudinal movement.

Figure 7. **54-0734** **Lavic Road OC**

Three (3) inches transverse shift along the bridge center line at north abutment.

Figure 8. **54-0734** **Lavic Road OC**

Lateral displacement at south abutment.

Figure 9. **54-0734** **Lavic Road OC**

Shear failure at north abutment.

Figure 10. **54-0734** **Lavic Road OC**

Considerable shear damage at north abutment.

Figure 11. **54-0734** **Lavic Road OC**

Detail of the damage at south abutment.

Figure 12. **54-0734** **Lavic Road OC**

3 ½" transverse movement in the superstructure.

Figure 13. **54-0734** **Lavic Road OC**

Considerable transverse movement in the northwest abutment and wingwall.

Figure 14. **54-0734** **Lavic Road OC**

Considerable transverse movement in the northwest abutment and wingwall.

Pisgah Overhead (Br. #54-0689 R / L)

Pisgah Overhead (Left and Right Structures) are two parallel, three (3) span steel plate girder bridges with composite ‘Cast-In-Place’ concrete slabs (See Figure 16, General Plan). Asphalt Concrete (AC) overlay is placed on both structures. Both bridges have a large skew of about 55 degrees. The earthquake damage was mostly restricted to the abutment locations. The west abutments sustained more damage than the east abutments. The damage is due to longitudinal and transverse movement of the bridges and the pounding of bridge barriers and decks to the adjacent barriers (Figure 15), decks, wingwalls and abutment walls. Damage was noted at the abutment expansion joints, at the sheared off wingwalls, and at cracked steel bearing pedestals.

When the bridges moved longitudinally, they engaged the abutment curtain walls. This resulted in shear cracks along the sides of abutments and wingwalls (Figures 17 and 18). Wingwalls and their barriers at abutment locations sustained damage due to the longitudinal and transverse movements of the bridges (Refer to Figures 15, 19 and 20).

There are two reasons for the cracks at steel bearing pedestals. First, some pedestals were previously cracked due to the presence of reactive aggregate in the concrete. Secondly, the previous cracks were most likely enlarged when the upper steel bearing plate engaged the bottom ‘U’ shaped part of the steel bearings (See Figure 22). The rubber layer between the plates served as an isolator, but was not thick enough to allow the upper plate unrestricted movement. The damage to the pedestals occurred at two out of four at each abutment. In general, bearings with smaller gaps between the bottom and top steel plates were cracked, while others with sufficient gap between the steel upper and bottom plates remained undamaged.

Figure 15. **54-0689 R/L** **Pisgah OH**

Barrier rail damage at South Abutment.

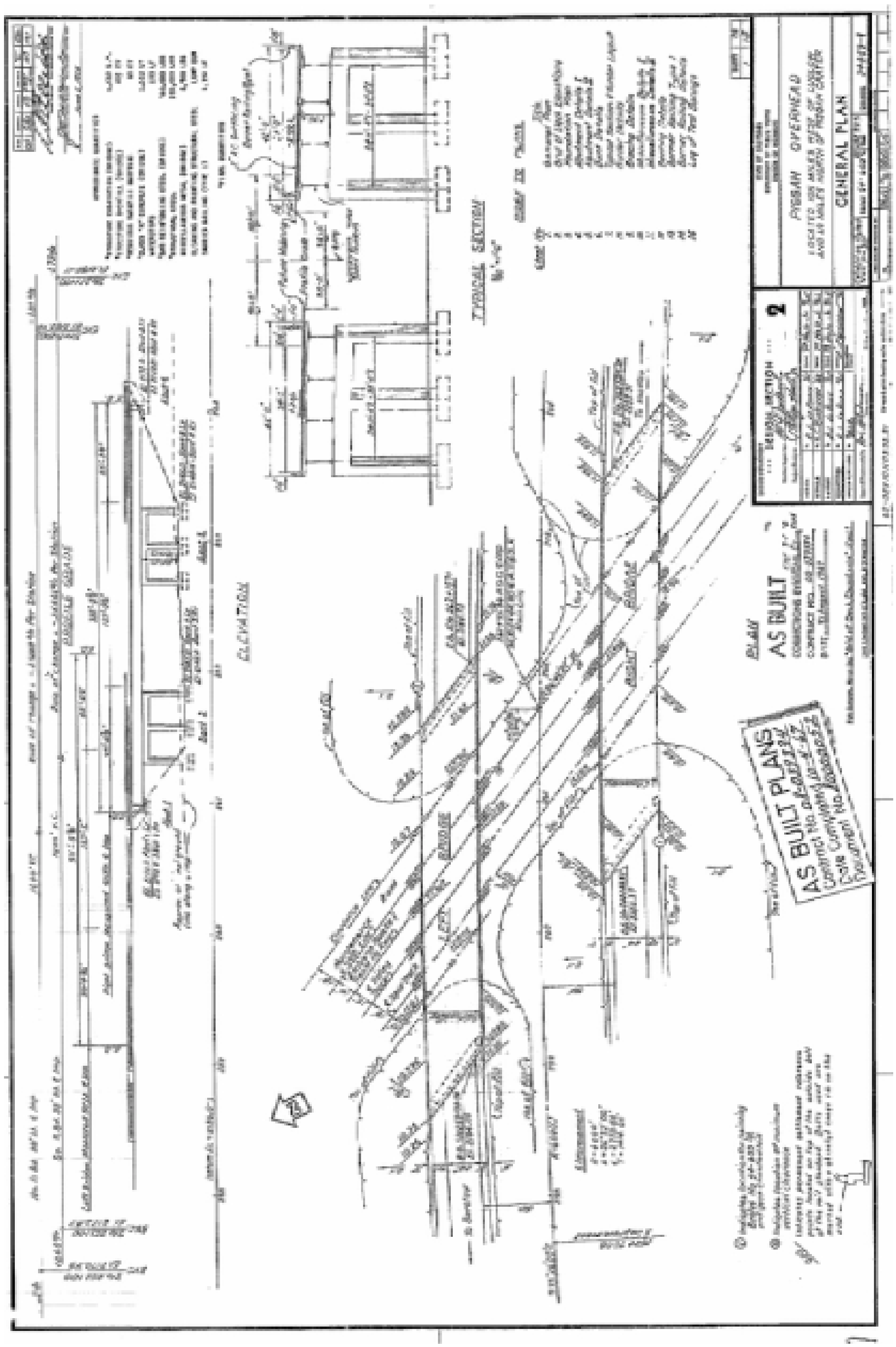

Figure 16. Pisgah Overhead L / R General Plan.

Figure 17. **54-0689 R / L** **Pisgah OH**

Figure 18. **54-0689 R / L** **Pisgah OH**

Details of shear damage at west abutment due to longitudinal and transverse movements.

Figure 19. **54-0689 R / L** **Pisgah OH**

Damages to barrier and wingwall due to longitudinal bridge movement.

Figure 20. **54-0689 R / L** **Pisgah OH**

Damage to barrier rail.

Figure 21. **54-0689 R / L** **Pisgah OH**

Steel bearing induced cracks.

Figure 22. **54-0689 R / L** **Pisgah OH**

Pedestal damage at west Abutment. Note small gap between top and bottom steel plates.

Cast-In-Place Concrete Slab Bridges

The PEQIT team investigated several cast in place concrete slab bridges in the area of Hector Mine earthquake. All of these structures were standard bridges supported on pile extensions. There was no damage to these structures except minor concrete cracking. PEQIT team members found evidence that the bridge abutments experienced movements of up to three inches in both the longitudinal and transverse directions. Soil around these abutments settled two to four inches. The pile extensions moved as well. Due to the pile movement/vibration the sand surrounding them was compressed and formed depressed cones around them. The maximum cone diameter found was about 48" with the pile extension in center, the maximum depth of depression was estimated to be approximately three inches. These findings are documented on two structures, where the described effects of the earthquake were the largest.

During the inspection of slab bridges we found cracks in abutments that in our opinion were not caused by the earthquake. These cracks are more likely result of reactive aggregates in the concrete.

Argos Wash Bridges (Br. # 54-0737 R / L)

Two parallel structures are standard slab bridges on pile extensions. There was no major damage to these structures except minor concrete cracking. There was no concrete spalling. We found evidence that the structures had moved approximately three inches in the longitudinal and transverse directions (Figure 25). Embankment settlement was up to four inches. The pile extensions had moved as well, resulting in sand cones forming around the piles at the surface level. The cones extended about 24" from the face of the pile extensions (See Figures 26 and 27).

Sand Hill Wash Bridges (Br. # 54-0736 R / L)

These bridges are also standard slab structures on pile extensions. The Sand Hill Wash bridges behaved similarly to the Argos Wash structures, only the described findings were smaller than in the case of the Argos Wash Bridges. It is our opinion that this was most likely due to more distance from the earthquake epicenter. The movements at the abutments were about two inches. There was no damage to these structures except minor concrete cracking. We could observe that the pile extensions had also moved in this case. However the size of cones formed in the sandy soil was smaller than in the case of Argos Wash Bridges. The cones extended only six inches from the face of the pile extensions (Figure 28).

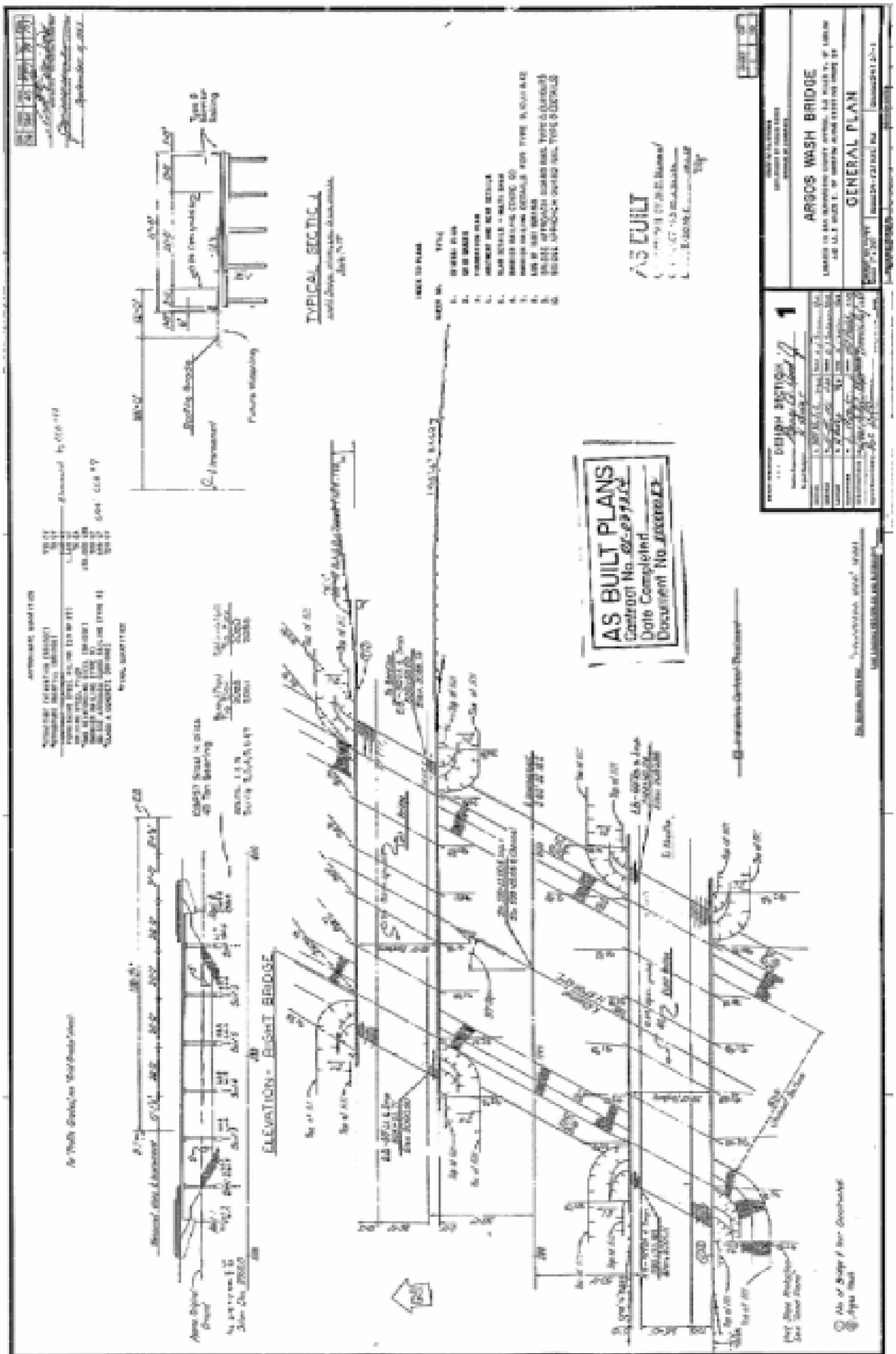

Figure 23. General Plan of Argos Wash Bridge.

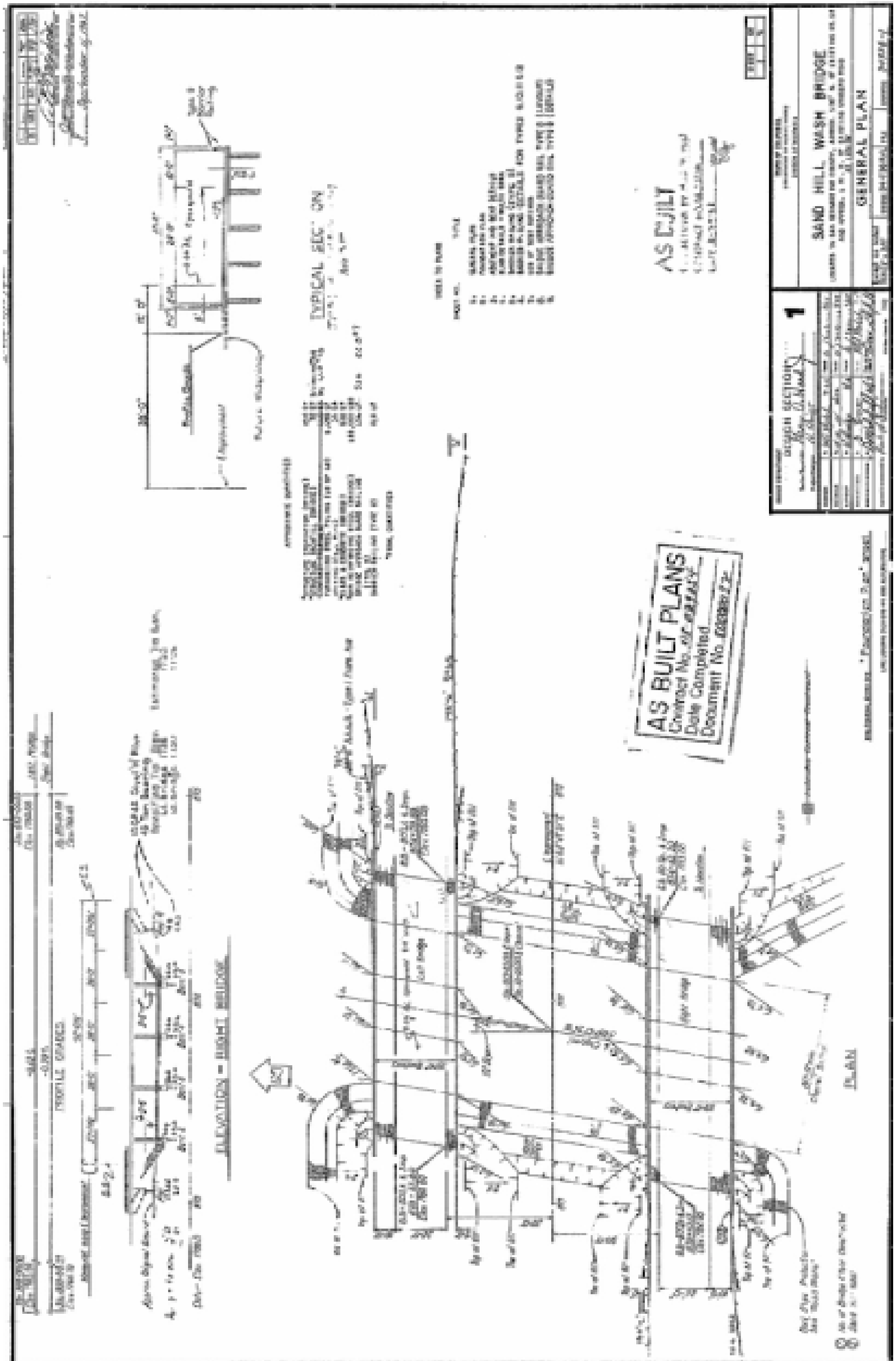

Figure 24. General Plan of Sand Hill Wash Bridges.

Figure 25 **54-0737 R/L** **Argos Wash Bridge**

Abutments experienced considerable movements with no damage.

Figure 26. **54-0737 R/L** **Argos Wash Bridge**

Approximately 3” settlement of sand around some CIDH piles / pile extensions.

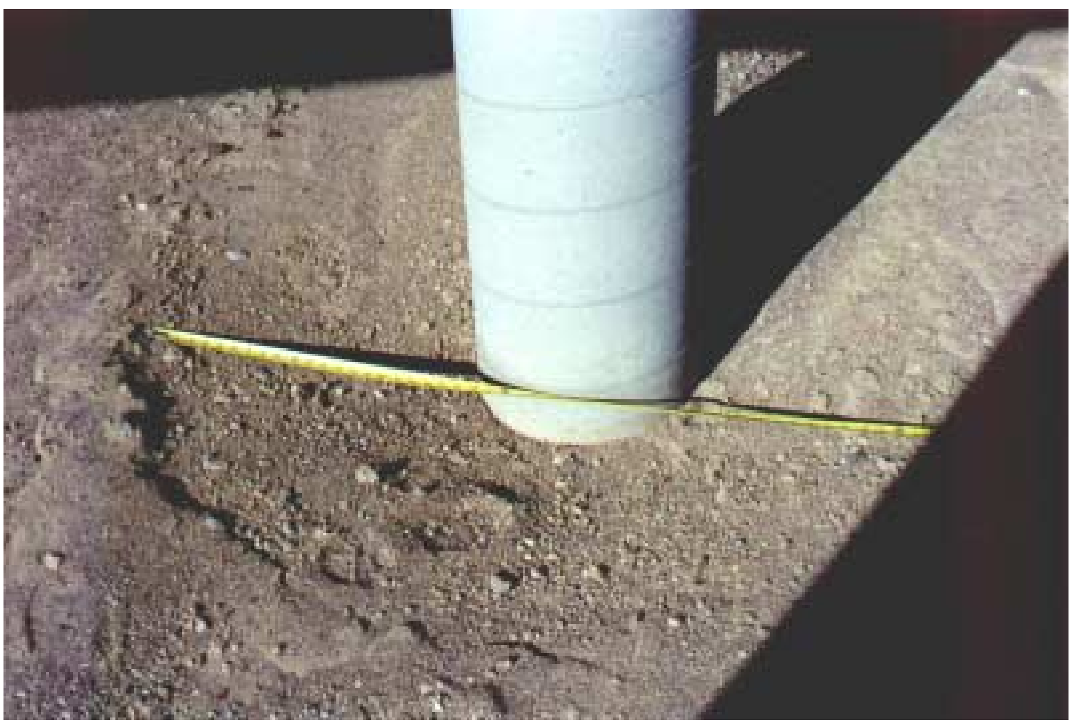

Figure 27. **54-0737 R/L** **Argos Wash Bridge**

Formation of soil cones around the pile extensions.

Figure 28. **54-0736 R/L** **Sand Hill Wash Bridge**
Movement / cones in the sand at the bottom of pile extensions were smaller than at Argos Wash bridges.

Fault Rupture

One of the main tasks assigned to PEQIT team was to locate the fault rupture. Due to the timing (on the weekend) the PEQIT team could not obtain an access permit to the "Marine Corps Air Ground Combat Center" and could not locate the largest ground rupture displacements. This task was accomplished later by other teams (See "Section II – Seismologist's Report" for details). However we made an effort to locate some displacements just outside of Marine Corps Base along Routes 40, 66, and 62.

Locating the fault rupture directly on Hwy I-40 pavement was difficult. We noticed only minor damage to freeway I-40 shoulders, with no visible cracks in the pavement. We found, however, more evidence on the pavement along the historic Rt. 66. Route 66 in this location is parallel and essentially a frontage road for I-40. Distance between the two routes is approximately 100 yards. There was some damage to the pavement on Route 66 due to the surface rupture. The offsets at the shoulder lines can be seen clearly on Figures 29 and 30. It is our opinion that this type of damage has been caused by a right-lateral strike-slip fault rupture causing the road pavement to shear.

Figure 29. **Route 66**

Moderate surface rupture and ground translation along Rte. 66 approx. 100 yards South I-40 and 300 yards North from Amtrak's derailed cars.

Figure 30. **Route 66**
Moderate surface rupture and ground translation along Rte. 66 approx. 100 yards south of I-40 and 300 yards north from Amtrak's derailed cars.

Conclusions

The Hector Mine earthquake caused relatively little damage to bridges. All damaged structures are located on Route I-40, even though the distance to Routes 15, 62, 247 and 10 is less than the distance to the I-40 freeway. Both the ABME and PEQIT teams were unable to locate any bigger damage to the structures on these other routes.

We may offer some reasons, why this happened. First, the area of Mojave Desert is sparsely populated. Therefore there are not too many bridges there (density of bridges is relatively low). Second, bridge structures are usually small, consisting of few spans. This is just the opposite of the situation after Loma Prieta and/or Northridge earthquakes, where large structures were exposed to strong ground motions. Third, all inspected structures employed better detailing practices than bridges damaged in past earthquakes. In addition, we also concluded that much of the damage to bridges during the Hector Mine earthquake was the worsening of pre-existing conditions.

The Lavic Road Overcrossing abutment cracking and spalling was in part the result of a long-standing problem with reactive aggregates that have slowly weakened the concrete. In fact, this bridge was being studied for repairs or possible replacement at the time of this earthquake (Refer to Figures 9, 12, and Appendix of this report).

The Pisgah Overhead structures has had a history of problems with weld fractures at the connections of steel girder web to vertical stiffeners (See Figure 31). PEQIT found a note beside a crack that goes back to the year 1993.

Figure 31. **54-0689 R / L** **Pisgah OH**

Crack in the girder web - vertical stiffener connection near West abutment of the bridge.

The reason for these defects could be the use of staggered cross-bracing that develops high stresses in this type of connection. Plans were drawn in 1991 to strengthen both bridges and to stop the spread of fractures on the girders (Figure 32). However, the problem continued and was exacerbated by the recent earthquake.

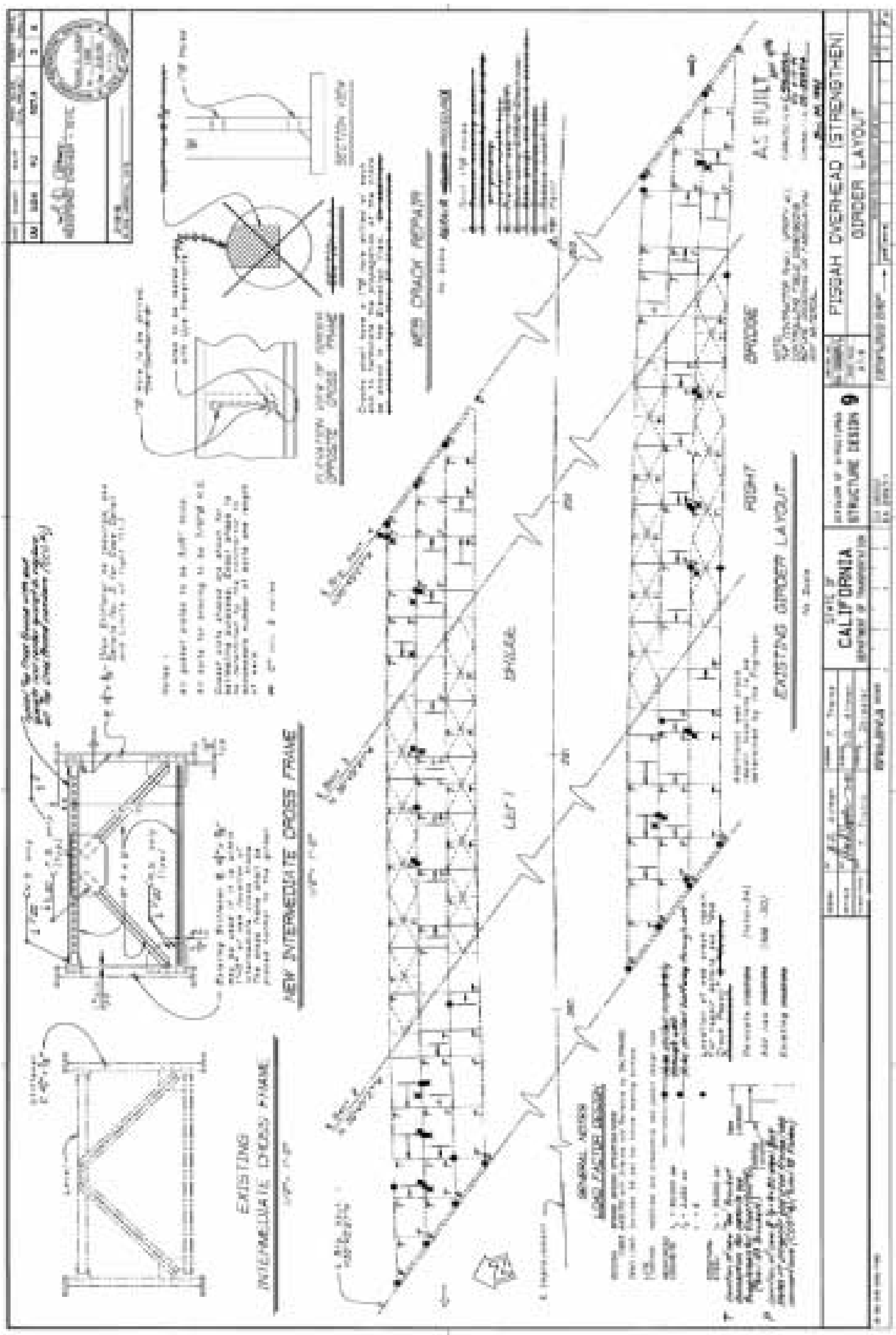

Figure 32. Strengthening of Girders at Pisgah Overhead.

The PEQIT team encountered one additional problem with investigating bridge damage in a highly seismic area such as the Mojave Desert. They realized that sometimes it is difficult to identify damage from the most recent earthquake or from a previous one. Team members had to carefully look for rust or other signs of aging to ensure they were not looking at damage from the 1992 Landers, 1992 Joshua Tree, or even from the 1986 North Palm Springs earthquake. For instance, Figure 33 shows abutment damage at Pisgah OH during the 1992 Landers earthquake. Figure 34, in our opinion, depicts the same location photographed after the 1999 Hector Mine earthquake.

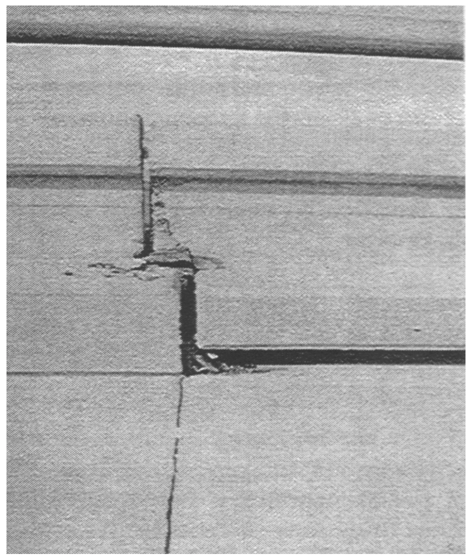

Figure 33. Abutment Damage at Pisgah OH after 1992 Landers Earthquake.

Figure 34. Abutment Damage at Pisgah OH Photographed after the 1999 Hector Mine Earthquake.

Similar to the Landers earthquake, the Hector Mine shake was relatively large, with a long duration, and with a lot of surface faulting, though producing a minimal damage even to adjacent structures. It will take much thought and research to determine why this happened and what lessons can be learned. Some research has already begun after previous earthquakes. This should give us a much better understanding of structural behavior in the future.